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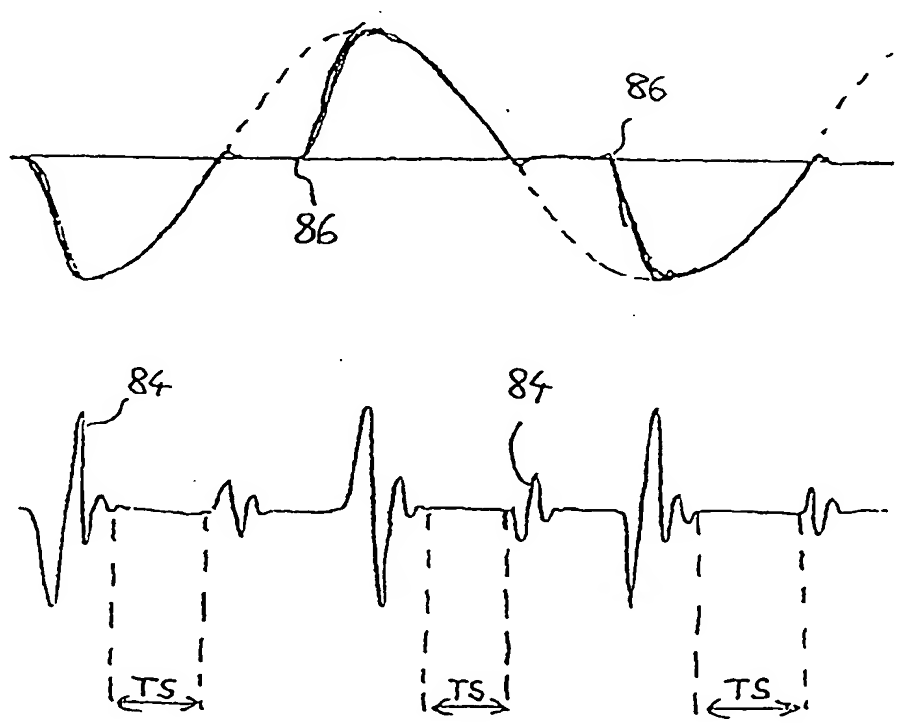
(54) Title: COMMUNICATION ON A SERIES CABLE

(57) Abstract

The present invention pertains to a method and a system for synchronization of time slots to a part of an a.c. net frequency half cycle as well as an apparatus for performing the synchronization. More particularly it relates to a transfer method and a system for communication of pulse signals over a series cable powered by a constant current regulator for control and monitoring of lightings, lamps, sensors, detectors and other loads. It specifically relates to the technical field of control and monitoring of airfield lighting systems (TWY1, TWY2, TWY3, SB1, LO1) including sensors for Surface Movement and Guidance Control Systems (SMGCS).



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COMMUNICATION ON A SERIES CABLE

Field of the invention

The present invention relates to a message transfer method and system for control and monitoring of lightings, lamps, sensors, detectors and other loads, more particularly for control and monitoring of airfield lighting systems including sensors for Surface Movement and Guidance Control Systems (SMGCS).

History of the prior art

The lamps for airfield lighting systems are most often fed by a constant current power supply via a series cable. Such lamps are connected in series with the supply cable using isolation transformers. A common type of automatic lamp monitoring system monitors the current and the voltage supplied to the series cable. If a lamp fails, the impedance in a loop of lamps changes, and this is reflected in the supplied current and voltage. A disadvantage with this method is that there is no information about which lamp has failed. It is therefore difficult to determine the urgency for replacing the lamp. Also, if a large number of lamps are attached to the loop circuit, the change in impedance caused by lamp failure can be so small that it becomes difficult to detect. If several lamps fail the change in impedance becomes greater.

Another type of monitoring system is based upon assigning a unique address along with a monitoring unit to each lamp. When the lamp fails, the unit short-circuits the lamp and periodically breaks the short-circuit in a timed sequence determined by the address of the lamp. Identification of the failed lamp is made by determining the time (with regard to some reference) in conjunction with measuring disturbances in voltage or current through a detector connected to the primary side of the series transformers. Again, the change of impedance due to lamp failure can be so small that it is difficult to detect, but this time the short-circuit for each lamp, one by one, is released so that only one lamp at the time signals a failure to a main monitoring unit.

Such prior art systems are known from U.S. Pat. No. 5,359,325 by Ford et al, European Pat. No. 0 445 773 by Taniguchi et al and European Pat. No. 0 448 358 by Watanabe. These systems are relying on the saturation of the series isolation transformers. An isolation transformer of the kind used in an airfield lighting system saturates, i.e. it acts like an air coil with almost no impedance when a lamp failure occurs on the secondary side of the transformer, thus creating disturbances on the primary side through the change of flux. The change of flux is detectable, but in some cases hard to differ from other disturbances as for example such created by the net frequency current zero crossings when the current is thyristor modulated as is common. It is especially difficult to detect

disturbances through flux changes when a lot of transformers are connected in series.

Further, these documents do not teach a communication during a short part of a net frequency half cycle (period). Signals in said cited documents are transferred over much longer time periods not regarding zero crossings. The inventions according to the above cited documents affect the impedance, but without concerning whether the impedance switches between high or low during a net frequency half cycle.

Another prior art document is disclosed through U.S. patent No. 4,398,178 by Russ et al which teaches a system for transmitting information on an alternating current line. This cited document has certain distinctive features, it has at least two conductors connected to an a.c. power source. Another feature involves that amplitude reductions are generated by means of a normally short-circuited impedance.

Further, document U.S. patent No. 4,398,178 indicates a method to transmit pulse signals from the current generator side to a number of receivers. The receivers respond according to a method which is not implementable on an airfield lighting system communicating on a series cable. It presumes a separate current transformer used only for communication because it is normally short-circuited. The transmitter unit communicates through interruptions of a short-circuited transformer (impedance).

Still further, its receiver units communicate through a load and not through a transformer. Hence, the disclosed system communicates with different devices for upward and downward communication.

Summary of the disclosed invention

The cited documents U.S. Pat. No. 5,359,325, European Pat. No. 0 445 773 and European Pat. No. 0 448 358 do not teach a communication during a short part of a net frequency half cycle which is essential for the function of the present invention. The present invention creates a voltage pulse during a short time of the net frequency half cycle. The total of likewise created pulses during a specific half cycle are transferred as a pulse signal on the series cable. This is not disclosed in said documents which signals are transferred over much longer time periods not regarding zero crossings. The inventions according to the latter documents also affect the impedance, but without concerning whether the impedance switches between high or low during a net frequency half cycle. The present invention involves always using a controlled high impedance for communicating pulses contained in pulse signals.

U.S. patent No. 4,398,178 as mentioned teaches a system for transmitting information on an alternating current line. This document has features differing from the

present invention. It has at least two conductors connected to an a.c. power source, the present invention has only one conductor connected. Another difference is to be found in that amplitude reductions are generated by means of a normally short-circuited impedance in contrary to the present invention which does not at all communicate with a short-circuited impedance, it communicates by short interruptions accomplished through a switch that is connected in series to the load.

Further, U.S. patent No. 4,398,178 indicates a method to transmit pulse signals from the current generator side to a number of receivers. The receivers respond according to a method which is not implementable on an airfield lighting system communicating on a series cable. It presumes a separate current transformer used only for communication because it is normally short-circuited. The transmitter unit communicates through interruptions of a short-circuited transformer (impedance) which differs entirely from the present invention which transformers are short-circuited only during a lamp failure.

Still further, its receiver units communicate through a load and not through a transformer. Hence, the disclosed system according to U.S. patent No. 4,398,178 communicates with different devices for upward and downward communication. In order to implement a system disclosed in U.S patent No. 4,398,178, for example, on an airfield system for monitoring of airfield lighting would require a total redesign of an existing system.

The present invention is easily adopted to an existing system. According to the present invention, existing current transformers are used for powering of a load and for generating high frequency pulse signals where a pulse signal contains a number of pulses and where every single pulse is created by pulse wise affecting the impedance during a short time (creates a high impedance) in comparison to a half cycle where current is flowing. The interruption of the secondary side circuit is thus so short that the influence on the power fed to a load is negligible.

The present invention generally relates to a system and a method for message transfer between a main control system and addressable monitor switches for a lighting system. Such switches are connected in series with the supply cable using isolation transformers and on the other hand attached to a load which they are monitoring. Examples of such loads could be lamps and sensors. A sensor could, for example, be of magnetic, inductive, optical type e.t.c. for detecting or sensing the presence of obstacles such as vehicles.

More particularly, the present invention provides a system and a method for

message transfer of control and monitoring information for an airfield lighting system. Such a system comprises a main control system which communicates in both directions with addressable Light Monitor Switches (LMS modules) and/or Sensor Interface Units (SIU modules) through a series cable fed with a.c. current, generally 50 or 60 Hz in frequency, from a main power supply. All communicating entities are connected to the series cable via standard lighting transformers. Message transfer in both directions (downward, upward) is taking part according to a method where every half cycle of the a.c. net frequency can be used for transmission of high frequency superimposed signals, whereby a specific time part of each a.c. frequency half cycle constitutes a time slot allowing entities taking part to send or receive control and status information.

In order to overcome the aforementioned problems, it is an object of the present invention to provide a method for synchronisation of a time slot within every half cycle of the a.c. net frequency so that harmonics which interfere with the relatively high frequencies used for message transmission are avoided. Harmonics of the net frequency are frequent due to the fact that the a.c. current often is controlled by means of thyristors which most certainly creates harmonics at zero crossings.

A further object of the invention is to provide a system with a message scheme comprising time slots for synchronized communication between involved entities.

Another object of the invention is to provide a communication system that can be easily integrated in an existing airfield lighting control system through small LMS and/or SIU modules attached to existing standard components such as standard lighting transformers, sensors, lamps, cables e.t.c. A main control system is similarly attached to the series cable through a standard transformer.

Yet another object of the invention is that the control and monitoring system is provided from the secondary side of transformers which is of great advantage compared to systems that are provided at the primary side of a transformer.

A still further object of the invention is to provide means for an immediate switching between a steady state sequence for monitoring of LMS and/or SIU modules and a state where orders are to be sent to the LMS and/or SIU modules from a main control unit.

The present invention particularly comprises a method for transfer of control and monitoring information between a main control and at least one addressable light monitor switch module or sensor interface unit module. The main control and each light monitor switch module and sensor interface module are connected to the primary side of each one

dedicated isolation transformer. Such a dedicated transformer has its primary side connected in series to a power cable fed with a.c. net frequency current by a constant current generator. Also connected to the current generator is a filter preventing high frequency signals from reaching the constant current generator. Said transfer is superimposed on the net frequency current for control and monitoring of loads in airfield lighting systems.

A part of a.c. net frequency half cycles constitute time slots for message transfer with high frequency superimposed high voltage pulses. The pulses are bearers of data in each time slot which pulses arise on the primary transformer side through short interruptions of a series circuit controlled by a control switch on the secondary transformer side. Interruptions taking place within a time slot create a controlled high impedance. The total of the interruptions, which each create a controlled high voltage pulse on the primary transformer side, constitute a pulse signal for transfer of data.

Transferring according to the present invention enables control of load functions and reading the state of connected loads. Every time slot is synchronized to a part determined to contain almost no or little net frequency distortion in comparison with said pulse signals.

Further, the present invention describes a system for performance of the above described method.

Still further, the present invention describes an apparatus for continuous synchronization of pulse signals to modulated a.c. net frequency half cycles. The apparatus is used for determining a time for which the amplitude signal area before said time is equal to the amplitude signal area following said time.

Further, it includes first means for integration of half cycle signal amplitude areas for the area during a preset time and for the area for the remaining half cycle time following said preset time. The integrations are compared with means for comparing the areas of the integrated amplitude signals. Outputs from the comparing operation are applied to control means for controlling said preset time to be o[illegible] by means for offsetting towards said time to be determined. Integration is repeated until said areas are equal in order to find the time an use it as reference for synchronization of pulse signals.

A preferred starting preset time value is the time for 1/4 of the cycle duration time of an unmodulated sinusoidal a.c. net frequency signal, i.e. 5 ms for 50 Hz and approximately 4,17 ms for 60 Hz.

Finally the apparatus according to the present invention could be used in the main

control system of an airfield lighting system connected to a series cable for time slot synchronization to a.c. net frequency half cycles.

Brief description of the drawing

For a more complete understanding of the present invention and for further objectives and advantages thereof, reference may now be had to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic blockdiagram layout of an existing prior art airfield lighting monitoring system including Light Monitoring Switches and a main control system according to the invention;

Fig. 2 - 4 are schematic block diagrams of some of the blocks in Fig. 1;

Fig. 5a and 5b are illustrations of a thyristor modulated net frequency curve and its high pass filtered response whit the fundamental frequency filtered out respectively;

Fig. 6 shows a scheme of square waves used to synchronize a time slot to the net frequency in a preferred embodiment;

Fig. 7 shows a circuit used to create square waves according to Fig. 6:

Fig. 8 shows a series circuit with its connectors and interfaces according to the invention;

Fig. 9 shows an airfield lighting system according to the present invention;

Fig. 10 shows how the information exchange is performed on a structural level;

Fig. 11 shows a timing sequence for the time slots according to the present invention; and

Fig. 12 shows a timing sequence for a sending of an order message.

Detailed description

Figures 1-5 illustrate, in conjunction with the related description, a prior art airfield lighting system according to principles as taught in a relating copending international application published as WO/ 94/13119 assigned to the assignee of the present invention entitled "Systems and Methods for Transmitting Pulse Signals" by Lars Millgård. The present invention is able to utilize such a system for the performance of its objectives.

The airfield lighting monitoring system shown in Fig. 1 includes a number of current supply loops 2 for lamps 4, only one of said loops being shown in its entirety in the Figure. Each lamp 4 is connected to its associated loop 2 via a secondary winding 5 of an isolation transformer 6, the primary winding 8 of which is series connected in the current supply loop, and via a light monitor switch (LMS) 10. Each current supply loop 2

is fed by a constant current regulator (CCR) 12 via a communicating Series Circuit Modem (SCM) 14. A concentrator unit (CU) 16 is connected in a multi-drop configuration to a group 18 of the communicating units 14. The units 14 and 16 will be described more closely below.

The CU unit 16 and its associated elements, described above, together form a sub-unit 20, which can e.g. be devoted to a certain part of the lighting system of an air field. The lighting system can include a required number of similar sub-units, of which some are indicated at 20' and 20".

The CU units 16 in said sub-units are connected to a central concentrator unit 22 via multi-drop modems.

The central CU unit 22 can be connected to a computer 24 with a display 25. The computer 24 can be further connected to other systems via for example a local area network (LAN) 26. The unit 22 and computer 24 can e.g. be localized in a control room 27, or at some other suitable place.

Generally, the isolation transformers used in a system supplied with constant current, the current flowing through the secondary winding is proportional to the current flowing through the primary winding and, within certain limits, independent of the load on the secondary side. The voltage across the primary winding is proportional to the voltage on the secondary side. The proportionality is in both cases mainly given by the relation between the number of wire turns on the windings

An SCM unit 14 detects responses from the LMS modules and reports the addresses of nonresponding modules via the local CU unit 16 to the central concentrator unit 22. In the central concentrator unit 22, the addresses are stored in a database accessible to the computer 24 in the control room 27.

On the display 25 the number of failed lamps 4 and the position of each failed lamp can be displayed. Different alarm criteria can be set in the central concentrator Unit 22 via the computer 24.

As will be described more closely below the communication between the LMS modules and the associated communicating unit is carried out by high frequency signals superimposed on the 50 Hz or 60 Hz current in the power cable.

A schematic block diagram of a LMS module 10 is shown in Fig. 2, also illustrating the connection of the lamp 4 into circuit with the secondary winding 5 of the transformer 6.

The LMS module 10 is schematically shown to include a switch 30 in series with

is fed by a constant current regulator (CCR) 12 via a communicating Series Circuit Modem (SCM) 14. A concentrator unit (CU) 16 is connected in a multi-drop configuration to a group 18 of the communicating units 14. The units 14 and 16 will be described more closely below.

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system at the airfield.

The system requires no extra cabling on the field as it operates on existing power cables.

The LMS module 10 may store its address in an EEPROM-memory 34, which permits the stored address to be changed or receive its address as a binary code

In a preferred embodiment of the control and monitoring system of the present invention it employs a main control, LMS and/or SIU modules that are attached to standard transformers at their secondary side. The SIU module is a programmable and addressable microprocessor based sensor interface module, having almost the same function for surface movement and guidance control sensors as an LMS module has for a lamp. It operates on the secondary side of an isolation transformer and meets the same environmental requirements as an isolation transformer and operates in the current range of 2,8 A - 6,6 A. A SIU module powers a sensor 9 as well as monitoring its output. A sensor output can be of the type presence detection, heading detection, sensor self test e.t.c. Generally, sensors used are pertained to Surface Movement and Guidance Control Systems (SMGCS). As mentioned, the system transfers information between the main control system and the LMS units 10 in both directions, address and control information from the control system and status information from the LMS module, the same is also valid for a SIU module.

Further, the information exchange is conducted through signalling of high frequency signals, i.e, high frequency in relation to net frequencies which often are 50 or 60 Hz in frequency, so the information transfer is preferably carried out on frequencies between, for example, 4-7 kHz. This generally low frequency band is chosen due to some drawbacks in signalling with yet higher frequencies when communicating on a series cable, like for instance:

- High attenuation during signalling between the primary and the secondary side of transformers;
- High attenuation in those lamp transformers which are attached to the cable loop;
- Creation of oscillation nodes in long series cables, and
- Crosstalk between different series cables.

One of the principles underlying the present invention relies on net frequency

synchronization which minimizes net generated distortions, and on encoding with minimal overhead where a small part is used for the purpose of addressing. The series circuits in an airfield lighting system are generally fed from a CCR 12. Significantly, current control is often performed by affecting its curve form, for example, through thyristor control, see Fig. 5a and 5b which are illustrations of a thyristor modulated net frequency curve and its high pass filtered response whit the fundamental frequency filtered out respectively. Since the curve form of the current thus deviates from a plain sinusoidal one, it contains harmonics 84 that may appear in the frequency range applying to the performed communication. Harmonics 84 of the basic frequency mostly occur when the current controlling device, e.g. thyristor, is turned on or off e.g. at the zero crossings 86 of the curve related to the modulated current. The LMS/SIU system according to the invention only creates TS synchronization for information transfer in time intervals within every half net cycle where the content of harmonics and other distortions is low in the a.c. net frequency current.

A preferred embodiment of the present invention uses transmission of "1" and "0" where one bit is sent every half cycle of the net frequency in a time slot TS, for example, of very short periods of 2-3 ms. A time slot is placed in the part of the half cycle where current is flowing through the transformer and where the influence of harmonics is at its lowest. Finding the part for the time slot could be empirical at the initialisation stage of a system using the present invention thus being valid for that specific system. The signalling for communicating from LMS/SIU modules is generated through very short interruptions of the secondary transformer side circuit, whereby a high impedance arises thus creating a pulse of high voltage on the primary side of the transformer for every interruption in the assigned time slot TS. Hence, the interruptions create high frequency pulses superimposed on the net frequency in the assigned time slot TS clearly distinguishable from distortions when detected by the SCM unit 60. The series circuit 30 controlled by the control circuit 32 switches for very short intervals thus creating a controlled high impedance on the secondary transformer side. The present invention involves always using a controlled high impedance for communicating pulses contained in pulse signals. It creates a voltage pulse during a short time of the net frequency half cycle. The total of likewise created pulses during a specific half cycle are transferred as a pulse signal on the series cable.

According to the present invention, existing current transformers, no additional transmitters, are used for powering of a load and for generating high frequency pulse

signals where a pulse signal contains a number of pulses and where every single pulse is created by pulse wise affecting the impedance during a short time (creates a high impedance) in comparison to a half cycle where current is flowing. The interruption of the secondary side circuit is thus so short that the influence on the power fed to a load is negligible.

If the interruptions on the secondary transformer side are longer e.g one net frequency half cycle, the transformer will saturate rendering almost no impedance, i.e., no creation of a high voltage pulse, but an hardly detectable distortion through the change of magnetic flux. It would, in relation to prior art, request a transmitter connected to the series cable by means of a specially designed transformer to create a high voltage pulse according to the present invention.

The receiver, situated in the SCM unit, of signals from LMS and/or SIU modules is disconnected only during those time slots where a transmission is ongoing. This implies that transmitters and receivers should be time synchronized, the accuracy should be in the range of 0.1 ms. For one skilled in the art it would have been natural to employ zero crossings for the synchronization of time slots to the net frequency. Unfortunately, such an approach has disadvantages pertaining to additional zero crossings due to harmonics with superimposed noise. In order to overcome such disadvantages the present invention discloses an embodiment for an inventive solution for synchronizing a time slot to said half cycles.

With reference to Fig. 6, one preferred solution relies on a method for determination of the center of gravity for that specific time t_G of the net frequency where the area beneath the curve for the half cycle is equal on both sides of t_G, i.e., the area to the left of t_G is expressed as Y1 and is equal to the area to the right of time t_G expressed as Y2. Note that the area around t_G is non symmetrical because of the modulation of the current from the current generator. Both transmitters and receivers are bound to compute the position of the center of gravity and thereby positioning the time slot for communication in relation to the time t_G.

The circuit according to Fig. 7 illustrates an inventive circuit embodiment for synchronization of time slots in relation to the time t_G for a supposed center of gravity according to Fig. 6.

There are other possible embodiments regarding synchronization within the scoop of the present invention for one skilled in the art, including software solutions. Further solutions for synchronization between a SCM unit 14 and LMS/SIU modules could be

such as filtering each half cycle signal, for example, with a suitable band-pass filter and using the time when e.g. half the peek value is recalled, possibly in combination with a phase locked loop technique. It is also within the scoop of the present invention to claim such solutions for a message transfer system relating to lighting systems, especially systems for airfields.

With reference to Fig. 6 and Fig. 7, Fig. 7 illustrates a circuit 79 for generating a square wave C0 which frequency equals the net frequency and which phase is such that its negative-edge coincides with the centre of gravity at the time t_G. An operational amplifier A1 is connected as an inverter I1. A2 and A3 are amplifiers connected as integrators (I2, I3). S1, S2 and S3 are semiconductor switches. FF is a flip-flop used as a frequency divider and VCO is an Voltage Controlled Oscillator. When C3 is high S2 leads and the integrator A2 integrates the area Y1, and when C2 is high S1 leads and A2 integrates the area Y2, but with reversed sign so that the output voltage from A2 at the C2 negative-edge is proportional to Y2-Y1. During the time when C4 is high, S3 is conducting, and if the output voltage from A2 is separated from zero, the output voltage from A3 will increase or decrease depending on the polarity of the A2 output voltage. Thus, the VCO will increase or decrease its output frequency. An output voltage from A3 will stay constant when the C0 frequency is equal to the net frequency and the phase for C0 is such that Y1=Y2. The feed back of signals C2, C3, C4 is accomplished through a gate circuit G.

Still referring to Fig. 6 and Fig. 7. In general any apparatus for synchronization of pulse signals to modulated a.c. net frequency half cycles performing the following in order to determine the time t_G that sets the centre of gravity for an a.c. half cycle amplitude signal can be used. The apparatus should have means 79 for determining a time t_G for which the area Y1 before the time t_G is equal to the area Y2 after the time t_G. The determination of the time t_G is performed with reference to an appropriate preset time at the beginning of a repeated cycle for determining the time t_G.

Further, said apparatus should comprise means 79 for continuous synchronization of pulse signals to modulated a.c. net frequency half cycles for determining a time t_G for which the amplitude signal area Y1 before said time t_G is equal to the amplitude signal area Y2 following said time t_G. Said means 79 should comprise first means I2 for integration of said half cycles signal amplitude areas Y1, Y2 for the area Y1 during a preset time and for the area Y2 for the remaining half cycle time following said preset time. The next measure taken is to compare the integrations with means I1, I2 for comparing the areas of

the integrated amplitude signals, applying the output from the comparison to control means I3 for controlling said preset time to be offset by means FF, G. The offset is inducing control towards said time t_G. Integration is repeated until said areas Y1, Y2 are equal in order to find the time t_G and use it as reference for synchronization of pulse signals.

A preferred preset times starting value could be the time for 1/4 of the cycle duration time of an unmodulated sinusoidal a.c. net frequency signal, i.e. 5 ms for 50 Hz and approximately 4,17 ms for 60 Hz.

An apparatus as described above could be used in the main control system of an airfield lighting system connected to a series cable for time slot synchronization to a.c. net frequency half cycles.

It is most probably correct to assume that a part around or adjacent to a centre of gravity for a modulated a.c. net frequency half cycles amplitude signal contains less distortions then other parts, for example, parts nearby a zero crossing of a modulated signal.

The encoding of the communicated signals relies on the synchronization to the net frequency and on a specific way of employing the time slots where every half cycle of the net frequency contains a time slot. Message transfer or communication is conducted according to a master/slave principle where a SCM is the master and the distributed LMS/ SIU modules are slaves. A SCM sends orders, addressing the LMS and/or SIU modules group related, and where the LMS/SIU modules responde with their status information (ON or OFF) in order each one half cycle in a time slot. The SCM sends messages (SCM messages) in programable (i.e. number of time slots) time intervals, for example, one message every 30:th half cycle. A message could among others contain a message number, an order and an address to the specific LMS group for which the message is intended. Each and every of the 30 time slots after a SCM message has a time slot number that is determined by the SCM message number and the specific sequence number for the time slot, i.e., its position following the SCM message. In this specific embodiment, at most 30 LMS are able to reply after a SCM message, thereafter a new SCM message is sent.

In conjunction with the installation of the message and monitoring method and system according to the present invention, every LMS/SIU module is assigned one or more group addresses and one or more time slots during which the LMS/SIU modules should respond with their status information, for example, ON, OFF or FAILURE. This

means that SIU modules with a requirement of a fast reply, for example, sensor equipped SIU modules, are assigned at least one time slot for every SCM message number, hence other LMS modules are assigned one time slot belonging only to one specific SCM message number. As mentioned, the SCM message is transmitted according to even time intervals, but the message number can be chosen such that the subsequent time slots contain answers from the LMS/SIU modules that for the time being are required an answer. When, for example, an order is sent, and addressed to a specific group, a reply from this group is expected as soon as possible as a receipt of the order and its acceptance. The message transfer sequences will be explained more in detail below.

Now with reference to Fig. 8 illustrating a series circuit 2 with its connectors and interfaces according to the invention. The light monitor switch system is designed for use in an airfield lighting control and can be integrated in existing series circuits. A small electronic module LMS and/or SIU module (SIU doted in Fig. 8) is attached to each load 4, 9 that is to be individually monitored and/or switched on/off. High frequency signals superimposed on the power mains are used for communication between entities. Thus, no additional cabling on the field is needed.

In this preferred embodiment, the system is specified for series circuits working with a current range of approximately 2.8-6.6 A and voltages up to 5 kV.

The LMS/SIU module is an individually addressable module where every module has its own set of parameters, defining its working range including its unique identity. Parameters will be described and listed below.

The SCM unit relays communication signals to and from the series circuits from modules such as LMS 10/SIU 11. It receives and transmits blocks of data from or to a CU unit 16 via, for example, RS-232C series communication cable 2.

Hence, the CU 16 distributes and collects information to and from respectively, a number of SCM units 60 depending on system complexity. The CU 16 itself communicates with either another CU 16 or another unit such as a personal computer (PC) 24,25 or other central processor based units depending on system complexity.

A series circuit filter (SCF) 62 prevents high frequency communication signals from reaching the CCR 12 of the circuit.

Transformers 6 are e.g. of the type Isolation Transformer FAA 830, 200 W. The LMS, SCF and SCM connectors 96 are e.g. of the type L-823. Further, the SCF connection 98 is accomplished with T-adapters across the CCR output.

Fig. 9 illustrates an Airfield Smart Part ® (ASP) controlled airfield lighting

system.

Each assembly of lights that are to be operated as a group, separate from other assemblies, is given an alphanumeric "Light function" designation TWY1, TWY2, TWY3, LO1, SB1 etc. Examples of such assemblies are stopbars (SB), lead on (LO) and taxiway (TWY) segments in a taxiway guidance system. In this embodiment each light may be part of up to four light function assemblies. Fig. 9 depicts a light connected to three light functions (G1,2,3).

A light function assembly may consist of lights connected to different series circuits. All lights attached to a series circuit, belonging to the same light function, are given a group address (G1, G2, G3, G4, G5) that is unique for that light function on that specific circuit.

All lights are given an individual address (A1, A2,..., A7, A8), unique for the circuit to which the light is attached. So called light fixtures with two, separately controlled lamps are given one address for each lamp.

Sensors in an ASP controlled airfield lighting system are designated as follows.

Each assembly of sensors, that are to be operated as a group, generally a transmitter and a receiver, is given an alphanumeric "Sensor function" designation.

A sensor 9 may have one or more inputs for self-testing e.t.c. Each sensor 9 input (maximum four in this embodiment) is given a group address, unique for the series circuit to which the sensor is attached. The sensor is attached via a Sensor Interface Unit (SIU) which is connected to the series circuit via an isolation transformer 4 and which communicates with the SCM 60 in the same way as LMS/SIU modules 10, 11.

All sensors are given an individual address, unique for the circuit to which its receiver is attached. In this embodiment, each receiver can have up to three inputs and four outputs that can be controlled with the address.

Information exchange is performed according to the structure shown in Fig. 10, the arrows are showing the exchange flow. The uppermost box in the figure constitutes the higher system level.

Communication between different levels is of the master/slave type, where the higher level always is the master. The master is polling the slaves, evaluating the answers and, if a specific programmed condition is fulfilled, the polling sequence is interrupted and an order is sent downward the system, whereby evaluation of entered or set conditions is performed at as low system level as possible. In order to achieve short response times, information is condensed as much as possible before it is transferred upward in the

system. Consequently, requirements on the channel for transmission of information can be kept on a low basis. In general only information about changes in status is transferred from one level to another. For example, information on the status of individual lights is only sent upwards in the system in case of a light failure. As long as the lamp is working, its status may be decided from the status of the light functions to which it belongs.

A protocol used for interfacing the communication to an external host system could be of the standard type, e.g., Allen-Bradley Data Highway+ or Omron Sysway System. As for protocols used for communication between CU and SCM and between LMS modules 10 or SIU modules 11 they are proprietary. Dependent on the application a RS-232, RS-485, short-haul modem or fiber optic modem may be chosen.

As for the communication between LMS/SIU modules and SCM units 60, signals are synchronized to the net frequency such that one bit is sent each half cycle where each bit consists of a burst of pulses. The frequencies in this preferred embodiment are chosen from, for example, the range 4-7 kHz as follows:

From SCM:	"1"=f1 (frequency 1)
	"0"=f3 (frequency 3)
From LMS	"1"=f2 (frequency 2)
	"0"=f3 (frequency 3)

SCM 60 frequently sends synchronizing signals, according to one of the methods described below, with or without orders to the LMS and/or SIU modules. LMS and/or SIU modules respond, one after the other during the time slot (half cycle) that is given by an individual address for an LMS or SIU. According to this manner, the LMS or SIU modules respond with a "1" if a load is ON and a "0" if it is OFF. In case of a load 4, 9 failure no respond signal is transmitted.

There exist two types of synchronizing signals: The "Shortsync" (SS) and the "Longsync" (LS). When no orders are transmitted an SS is repeatedly transmitted for LMS/SIU modules monitoring purposes. An LS contains an order which is only transmitted when a new order is to be carried out and it is repeated until satisfactory responses are received from the LMS/SIU module. The SS and the LS are both numbered from #1 to #8in this embodiment, but preferably programmable.

Now referring to Fig. 11 for an illustration of the Shortsync procedure. The time

between Shortsyncs is given by the number of occupied time slots between synchronization-words (sync-words). It is preferred that each LMS or SIU module can be allotted two time slots following each one of the eight possible sync-words, but generally only one time slot following one of the eight sync-words is allotted to an LMS.

Considering a sensor 9 as a load, a SIU generally is allotted one time slot after each one of the eight sync-words. Fig. 11 depicts an example where a total of 240 time slots are used for communication which corresponds to an airfield lighting system with e.g. 240 LMS modules or 160 LMS modules and 10 SIU modules. The time period for a net frequency of 60/50 Hz regarding one sync-word and 30 time slots is 304 or 380 ms respectively, and the total for eight sync-words and 240 time slots is 2432 or 3040 ms respectively. As mentioned, sync-words are transmitted and time slots are allotted repeatedly. Therefore, sync-word #1 is sent after the elapsing of time slot 240 and the procedure is cyclically repeated in a steady state sequence, if not interrupted by a Longsync.

Still referring to Fig. 11 for an explanation of the fields in the Short-sync which are Startbit, No, Identifier and Checksum [Startbit No Id CRC]. The Shortsync contains 8 bits, one bit for the startbit, 3 bits for No (nnn), one bit for Id and 3 bits for the checksum (ccc). The startbit "1" corresponds to a frequency used only by the SCM units and not by the LMS and/or SIU modules. The three number bits nnn decide from which LMS a response is requested and the Id field corresponds to [0 = Shortsync]. To minimize the risk of false detection due to distances a checksum (ccc) according to a Cyclic Redundancy Code (CRC) is added. CRC codes are well known in the art, hence a detailed description of the technique is omitted.

Referring to fig. 12 for the transmission of LS. When an order is to be transmitted, the steady state sequence is disrupted, except for that the last transmitted Shortsync number sequence is allowed to finish, for instance sequence #7 if applicable. Subsequently, the Longsync-word with the appropriate order is transmitted, whereby the synchronization number (sync #) is chosen such that it corresponds to when the addressed group has a time slot to respond within.

See Fig. 12 for an explanation of the fields in the LS which are Startbit, No, Identifier, Checksum, Group No, Order and Checksum [Startbit, No, Id, CRC1, Groupadr, Order, CRC2]. The LS contains 23 bits, one bit for the startbit, 3 bits for No (nnn), one bit for Id and 3 bits for the checksum (ccc). The three number bits nnn decide from which LMS and/or SIU a response is requested and the Id field corresponds to [1 = Longsync]. To ensure a first checksum (ccc) a CRC code is added for detection of faults

in the No and Id fields. The Group address contains 7 bits (ggggggg) for addressing the order to the intended group. Next field contains the specific order through 4 bits (zzzz). An order, for example, can be of the type (0000) meaning turn on lamp, (0001) turn off lamp, (0010) flash lamp, etc. The last 4 bits in the second CRC field are determined and calculated through a polynomial named CRC-BCH $= x^4+x+1$

The LMS and/or SIU modules have their own sets of parameters which are defined through two blocks. Block 1 contains the parameters Timeslot and Group Addr and are downloaded during initialisation or changing of system configuration. The time slot approach has been covered above. Group Addr defines which group order to react upon. Since an LMS may be a part of several groups, up to four group addresses (A-D) in this embodiment may be defined. In practice this means that a LMS that has its group address set to, for example (10, 64, 0, 0,) responds to orders received when the group address for the order is 10 or 64.

A second block (block 2) in this embodiment contains, for example, the following parameters:

Destination Group Adr - Parameter block 2 is downloaded to all LMS and/or SIU modules that have one of their group addresses set to a number corresponding to the Destination Group Address in parameter block 2;

Default - Default status (on=1/off=0) for the LMS and/or SIU modules when the series circuit is powered up;

Inverse Func - States that the LMS shall accomplish the opposite of an on/off order, i.e. turn on the lamp when the order is off and vice versa (no inverse function=0, inverse function=1);

Safe Status - If communication is interrupted for a time longer than the time specified below through the parameter Timeout, the LMS and/or SIU shall switch the lamp On=1, Off=0 or NoChange=2 according to this setting;

Min ALC f_1 - Minimum signal level for detection of received data "0"; and

Min ALC f_3 - Minimum signal level for detection of received data "1".

A steady state sequence is given by Shortsync#1 Shortsync#2...Shortsync#8 Shortsync#1 Shortsync#2... e.t.c. The time between the shortsyncs is given by the number of occupied time slots between the syncwords. Time slot 0 is represented by the first half net cycle after the Shortsync. A possible modification to the steady state sequence is, if

there is a missing response from a previously responding LMS, the same Shortsync# could be repeated. If the response from the LMS is still missing after the repetition, the connected lamp (load) is assumed to have failed.

When an order sequence is to be transmitted, the steady state sequence is disrupted except for that the last Shortsync#-sequence is allowed to be finished and a Longsync-word with an appropriate order is sent. The sync# is chosen such that responses from the addressed group are achieved immediately after the Longsync. A possible modification is, unless LMS or SIU modules in the addressed group respond with correctly changed status, that the same longsync-word is repeated.

If an LMS and/or SIU has received a download order, the checksum is controlled. In case of parameter block 1, it is also checked if a lamp or load is disconnected. If that is the case, and if a Longsync-word is received after the parameter block (as a check of communication), the new parameters are stored in the LMS or SIU modules EEPROM. Otherwise the modules are reset and the previously used parameters are used. If two Shortsyncs are received before a Longsync, the LMS and/or SIU are also reset.

At a reset, the parameters stored in the EEPROM are loaded into a workmemory and a checksum is calculated and compared with the checksum stored in the EEPROM. Then, if a checksum-error is detected, the lamp is turned off, slot addresses and group addresses are removed and the other parameters are set to the default values, as given.

The checksum is calculated for parameter block 2 plus group addresses 1-4 using CRC-CCITT. This 2-byte checksum is stored in the EEPROM. Download parameters can be controlled by means of "checksum-questions" and used for comparison with the two bytes in the "checksum-question" where the most significant bit in each byte is disregarded.

Although the foregoing specification describes only the embodiments of this invention shown and/or described, it should be clear that other embodiments may be articulated as well.

Thus, the terms and expressions used herein serve only to describe the invention by example and not to limit the invention. It is expected that others will perceive differences which, while different from the foregoing, do not depart from the scope of the invention herein described and claimed. In particular, any of the specific constructional elements described may be replaced by any other known elements having equivalent function.

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Claims

1. A method for transfer of control and monitoring information between a main control (14, 16, 24) and at least one addressable light monitor switch module (10) or sensor interface unit module (11), said main control, each light monitor switch module (10) and sensor interface module (11) being connected to the primary side of each one dedicated isolation transformer (6) which primary side is connected in series to a power cable (2) fed with a.c. net frequency current by a constant current generator (12) having a filter (62) connected preventing high frequency signals from reaching the constant current generator, said transfer being superimposed on said net frequency current for control and monitoring of loads (4, 9) in airfield lighting systems, **characterized** in that a part of the a.c. net frequency half cycles constitute time slots for message transfer with high frequency superimposed high voltage pulses which are bearers of data in each time slot, said pulses arising on the primary transformer side through short interruptions of a series circuit (30) controlled by a control switch (32) on the secondary transformer side, said interruptions creating a controlled high impedance whereby said interruptions take place within said time slot, the total of said interruptions, each creating a high voltage pulse, on the primary transformer side constituting a pulse signal for transferring said data, said transfer enabling control of load functions and reading the state of loads, said time slots being synchronized to said part determined to contain almost no or little net frequency distortion in comparison with said pulse signals.

2. A method according to claim 1, **characterized** in that a pulse signal carries one digital data bit in each time slot whereby said pulse signal contains a burst of high voltage pulses superimposed on a.c. net frequency half cycles.

3. A method according to claim 1 and 2, **characterized** by determining the center of gravity for said a.c. net frequency half cycles and using it as a reference for synchronization of said time slots through determination of a time (t_G) for which the net frequency signal amplitude area on both sides of the net frequency half cycle is equal on said sides.

4. A method according to claim 3, **characterized** in that the determination of the time (t_G) is conducted through integration of the areas (Y1, Y2) one by one, comparing the areas, determinig the offsett and repeatedly integrating until they match each other.

5. A method according to any previous claim, **characterized** in that all loads (4, 9) connected to the series circuit are given an individual address, unique for the circuit to which the load is attached.

6. A method according to claim 5, **characterized** in that light fixtures with separately controlled lamps are given one address for each light fixture lamp.

7. A method according to claim 5 and 6, **characterized** in that each assembly of loads which are to be operated as a group, separate from other assemblies is given a alpha numeric load function designation (TWY1, LO1, SB1).

8. A method according to claim 7, **characterized** in that each light monitor switch module (10) and sensor interface module (11) is assigned one or more group address which group addresses belong to each a specific load function.

9. A method according to claim 8, **characterized** in that said modules are assigned one or more time slots (TS) during which they should respond with their status information.

10. A method according to any previous claim, **characterized** in that the sequences for establishing transmission of monitoring and control information in both directions on series cables between communicating entities are constituted by cyclically transmitting a number of synchronising signals of a first and a second type from the main control (14), each number being programmable, each of said synchronizing signals being followed by a programmable number of time slots (TS).

11. A method according to claim 10, **characterized** in that the first type of synchronizing signal triggers sequence used for monitoring purposes and that the second type of synchronizing signal triggers a sequence where orders are to be transmitted.

12. A method according to claim 11, **characterized** in that the second type of synchronising signal has priority over the first type of synchronizing signal thus allowed to break said first type of synchronizing signal sequence when orders are to be transmitted.

13. A method according to claim 12, **characterized** in that time slots following said first synchronizing signal are allowed to be finished.

14. A method according to claim 13, **characterized** in that the second synchronizing signal is chosen such that responses from addressed groups are achieved immediately after said second synchronizing signal.

15. A method according to claims 9 - 14, **characterized** in that in case of a missing response from a previously responding light monitor switch module (10) or sensor interface module (11) the same synchronization signal in said programmable number is repeated and upon a still missing response, the load is assumed to have failed.

16. A system for transfer of control and monitoring information between a main control (14, 16, 24) and at least one addressable light monitor switch module (10) or

sensor interface unit module (11), said main control, each light monitor switch module (10) and sensor interface module (11) being connected to the primary side of each one dedicated isolation transformer (6) which primary side is connected in series to a power cable (2) fed with a.c. net frequency current by a constant current generator (12) having a filter (62) connected preventing high frequency signals from reaching the constant current generator, said message transfer being superimposed on said net frequency current for control and monitoring of loads (4) in airfield lighting systems, **characterized** in that a part of the a.c. net frequency half cycles constitute time slots for message transfer with high frequency superimposed high voltage pulses which are bearers of data in each time slot, said pulses being created on the primary transformer side through short interruptions of a series circuit (30) controlled by a control switch (32) on the secondary transformer side, said interruptions creating a controlled high impedance whereby said interruptions take place within said time slot, the total of said interruptions, each creating a high voltage pulse, on the primary transformer side constituting a pulse signal for transferring said data, said transfer enabling control of load functions and reading the state of loads, said time slots being synchronized to said part determined to contain almost no or little net frequency distortion in comparison with said pulse signals, said time slots being synchronized through a series circuit modem (60) connected to a series circuit transformer (6), whereby said high voltage pulses are generated through existing transformers (6) through said modules (10, 11).

17. A system according to claim 16, **characterized** in that a pulse signal carries one digital data bit in each time slot whereby said pulse signal contains a burst of high voltage pulses superimposed on a.c. net frequency half cycles.

18. A system according to claim 16 and 17, **characterized** by determining the center of gravity for said a.c. net frequency half cycles and using it as a reference for synchronization of said time slots through determination of a time (t_G) for which the net frequency signal amplitude area on both sides of the net frequency half cycle is equal on said sides.

19. A system according to claim 18, **characterized** in that the determination of the time (t_G) is conducted through integration of the areas (Y1, Y2) one by one, comparing the areas, determinig the offsett and repeatedly integrating until they match each other.

20. A system according to claims 16-19, **characterized** in that all loads (4, 9) connected to the series circuit are given an individual address, unique for the circuit to which the load is attached.

21. A system according to claim 20, **characterized** in that light fixtures with separately controlled lamps are given one address for each light fixture lamp.

22. A system according to claim 20 and 21, **characterized** in that each assembly of loads which are to be operated as a group, separate from other assemblies, is given a alpha numeric load function designation (TWY1, LO1, SB1).

23. A system according to claim 22, **characterized** in that each light monitor switch module (10) and sensor interface module (11) is assigned one or more group address which group addresses belong to each a specific load function.

24. A system according to claim 23, **characterized** in that said modules are assigned one or more time slots (TS) during which they should respond with their status information.

25. A system according to claims 16 - 24, **characterized** in that the sequences for establishing transmission of monitoring and control information in both directions on series cables between communicating entities are constituted by cyclically transmitting a number of synchronising signals of a first and a second type from the main control (14), each number being programmable, each of said synchronizing signals being followed by a programmable number of time slots (TS).

26. A system according to claim 25, **characterized** in that the first type of synchronizing signal triggers a sequence used for monitoring purposes and that the second type of synchronizing signal triggers a sequence where orders are to be transmitted.

27. A system according to claim 26, **characterized** in that the second type of synchronising signal has priority over the first type of synchronizing signal thus allowed to break said first synchronizing signal sequence when orders are to be transmitted.

28. A system according to claim 27, **characterized** in that time slots following said first synchronizing signal are allowed to be finished.

29. A system according to claim 28, **characterized** in that the second synchronizing signal is chosen such that responses from addressed groups are achieved immediately after said second synchronizing signal.

30. A system according to claim 24 - 29, **characterized** in that in case of a missing response from a previously responding light monitor switch module (10) or sensor interface module (11) the same synchronization signal in said programmable number is repeated and upon a still missing response, the load is assumed to have failed.

31. An apparatus for continuous synchronization of pulse signals to modulated a.c. net frequency half cycles, **characterized** by means (79) for determining a time (t_G)

for which the amplitude signal area (Y1) before said time (t_G) is equal to the amplitude signal area (Y2) following said time (t_G), said means (79) comprising first means (I2) for integration of said half cycles signal amplitude areas (Y1, Y2) for the area (Y1) during a preset time and for the area (Y2) for the remaining half cycle time following said preset time, comparing said integrations with means (I1, I2) for comparing the areas of said integrated amplitude signals, applying the output from the comparation to control means (I3) for controlling said preset time to be offset by means (FF, G) for offsetting towards said time (t_G), repeating the integration until said areas (Y1, Y2) are equal in order to find the time (t_G) an use it as reference for said synchronization of pulse signals.

32. An apparatus according to claim 31, **characterized** in that said preset times starting value is the time for 1/4 of the cycle duration time of an unmodulated sinusoidal a.c. net frequency signal, i.e. 5 ms for 50 Hz and approximately 4,17 ms for 60 Hz.

33. An apparatus according to claim 31 or 32, **characterized** in that the apparatus is used in the main control system of an airfield lighting system connected to a series cable for time slot synchronization to a.c. net frequency half cycles.

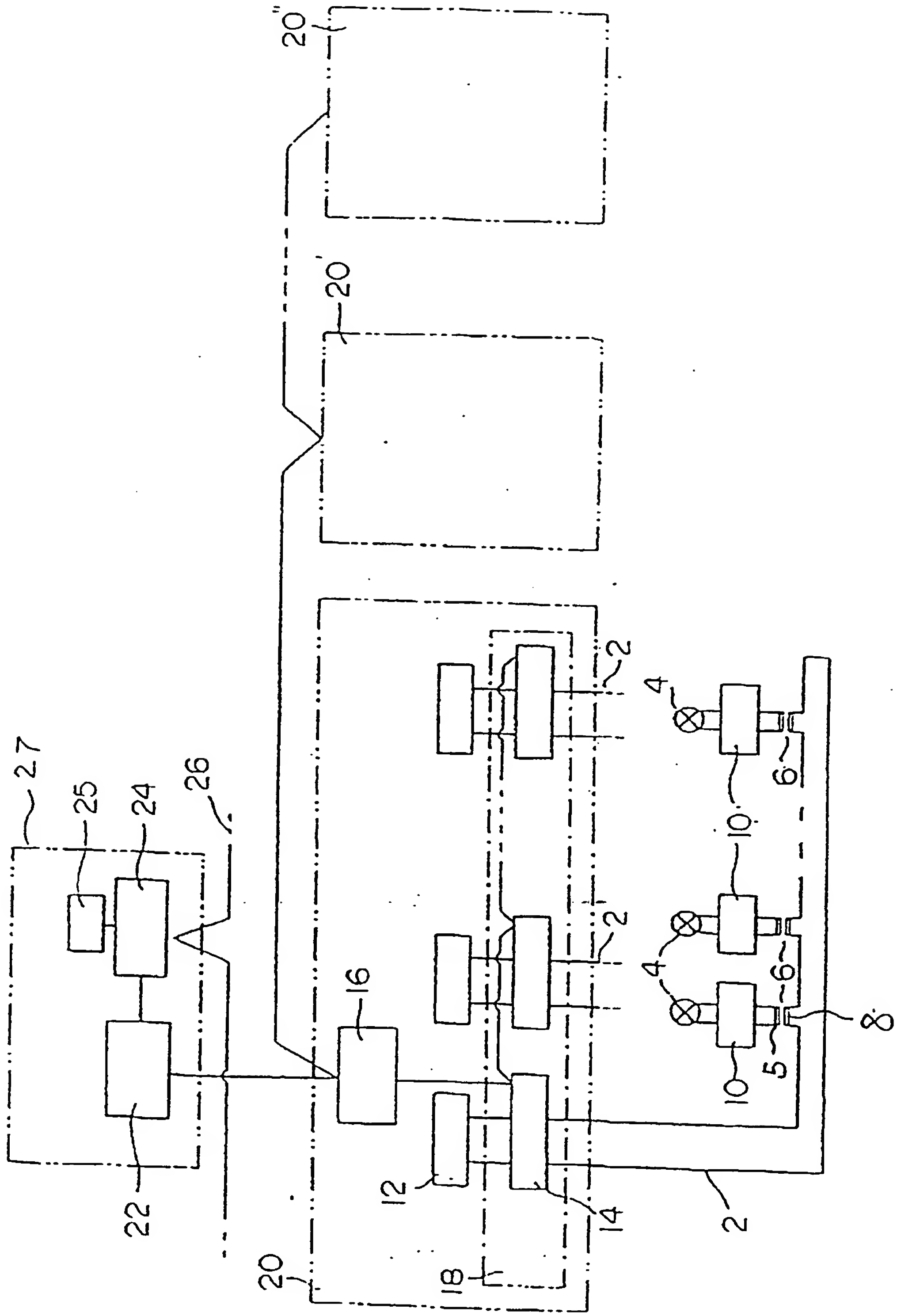


Fig. 1

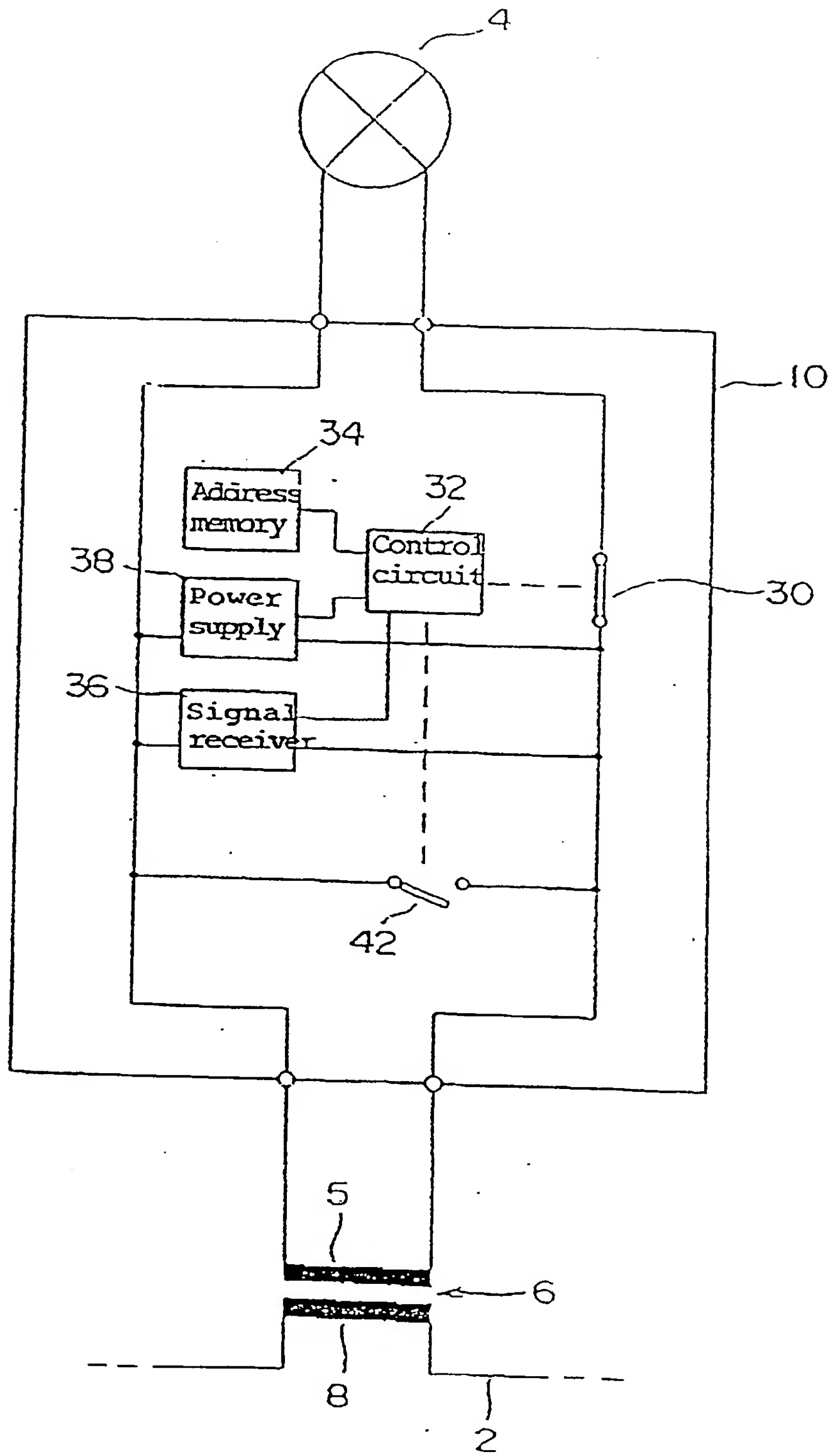

4
10
34
Address memory
32
Control circuit
38
Power supply
30
36
Signal receiver
42
5
6
8
2

Fig. 2

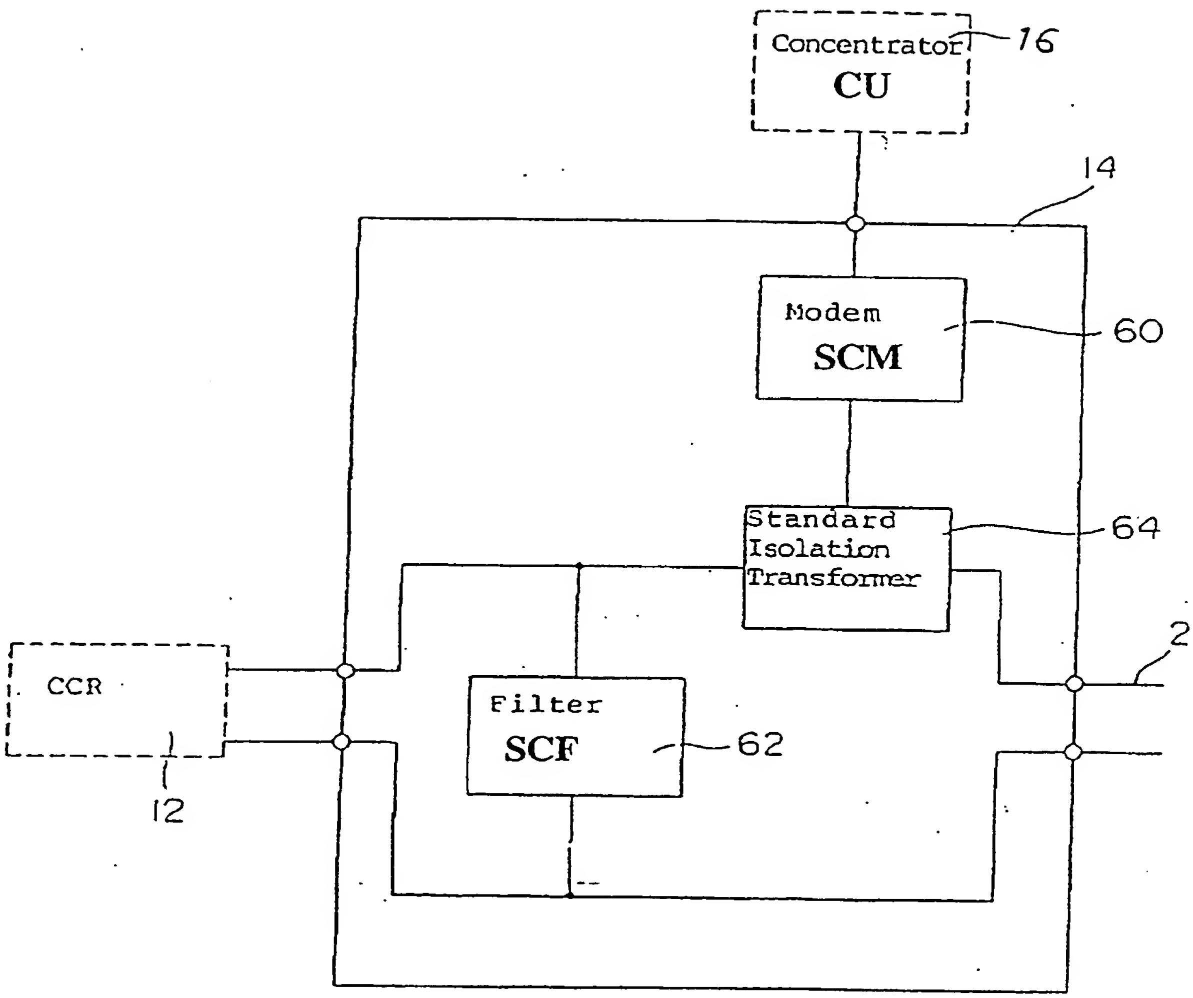

Concentrator
CU
16
14
Modem
SCM
60
Standard
Isolation
Transformer
64
CCR
12
Filter
SCF
62
2

Fig. 3

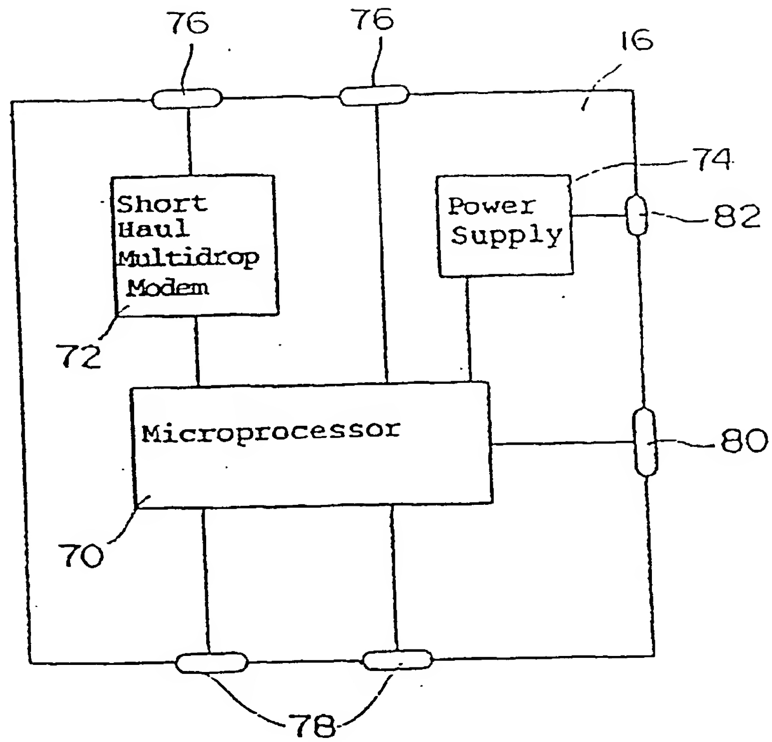


Fig. 4

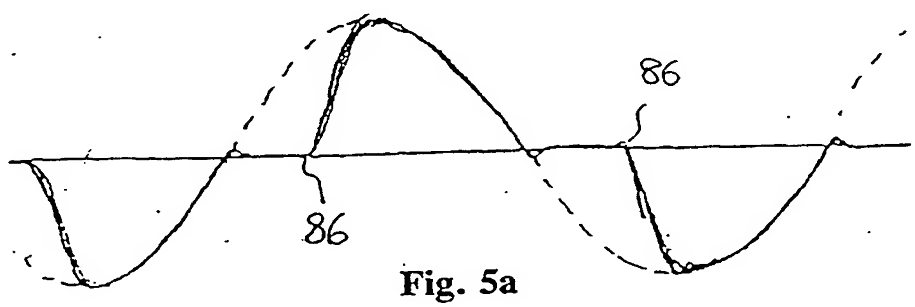


Fig. 5a

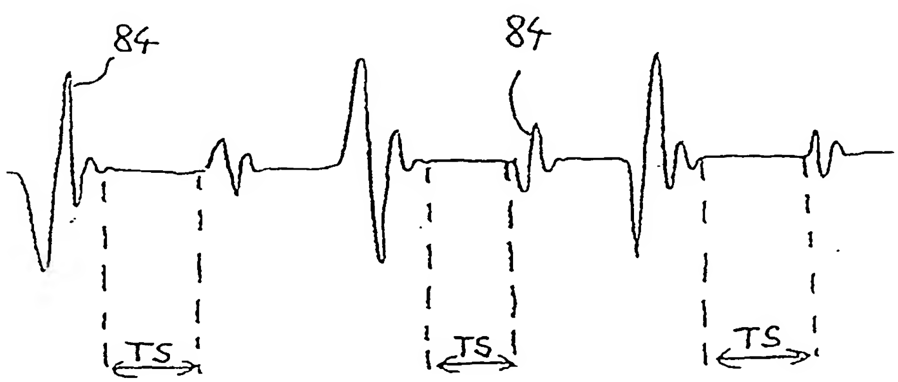


Fig. 5b

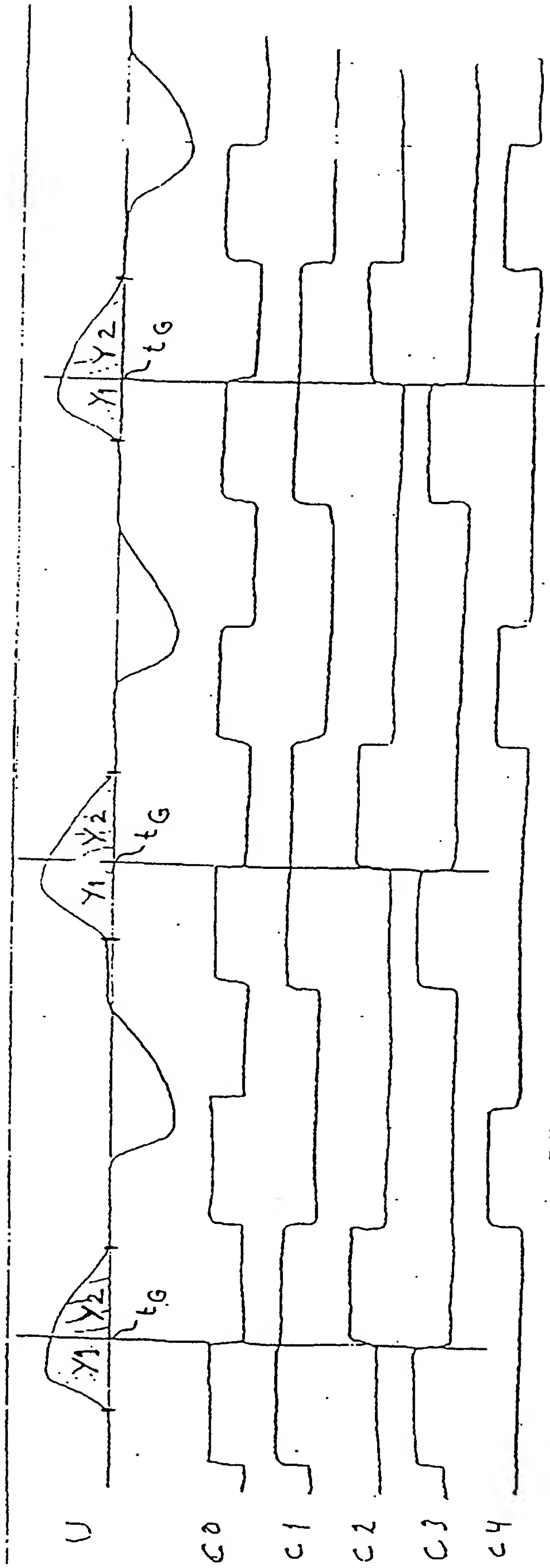

U
C0
C1
C2
C3
C4
Y1
Y2
tG

Fig. 6

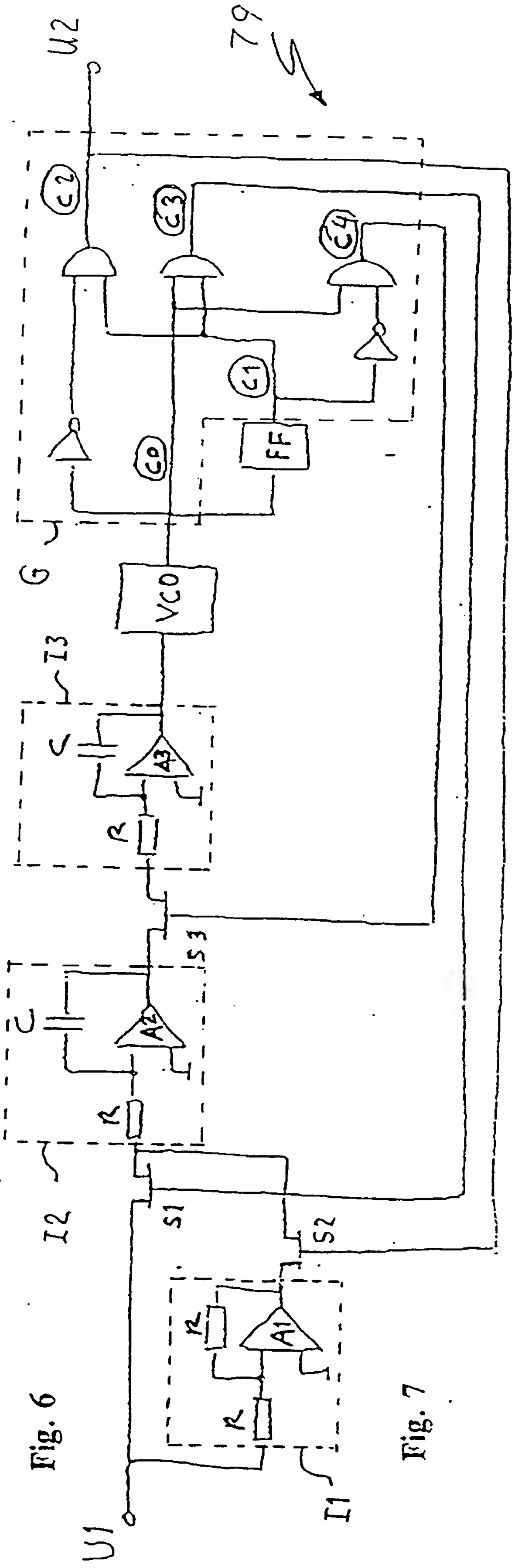

U1
U2
79
I1
I2
I3
A1
A2
A3
R
C
S1
S2
S3
VCO
G
FF
C0
C1
C2
C3
C4

Fig. 7

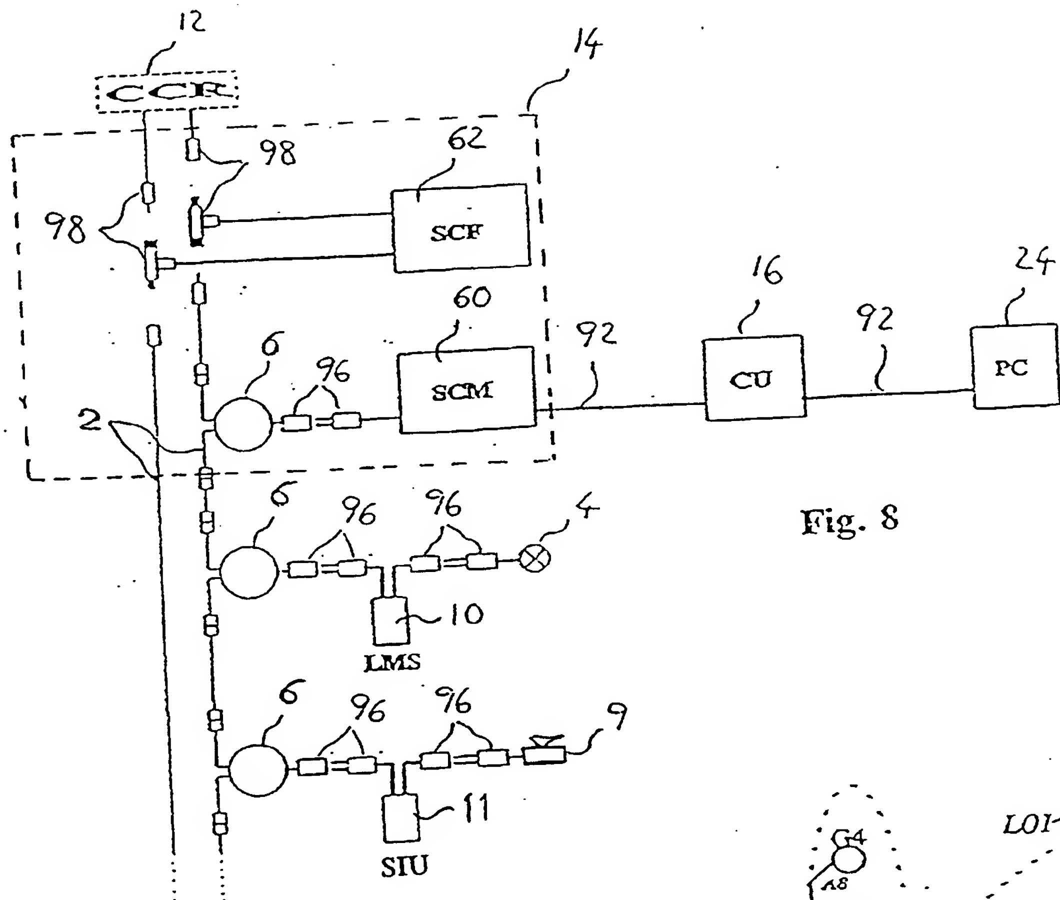

12
CCR
14
98
62
SCF
98
16
24
60
92
92
6
96
SCM
CU
PC
2
6
96
96
4
10
LMS
6
96
96
9
11
SIU

Fig. 8

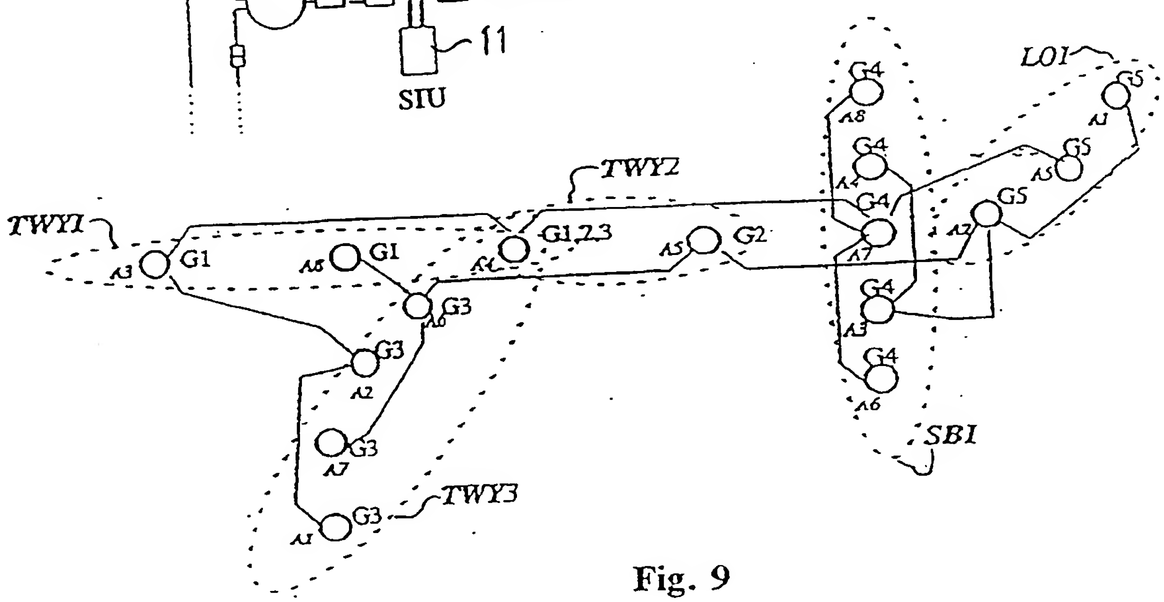

LO1
TWY2
TWY1
G1
G1
G1,2,3
G2
G3
G3
G3
G3
TWY3
G4
G4
G4
G4
G4
G5
G5
G5
SB1

Fig. 9

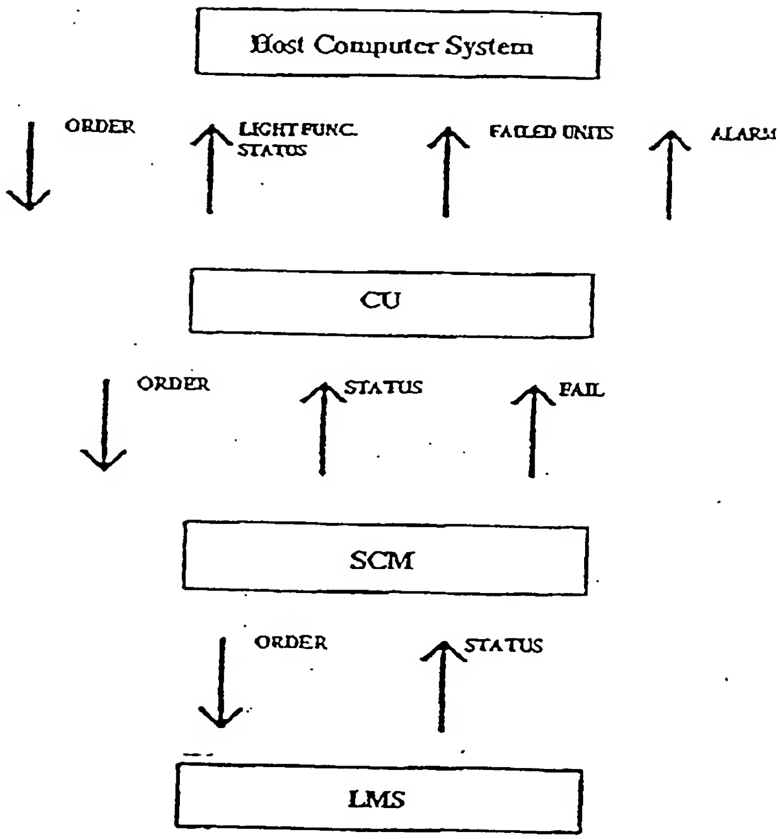
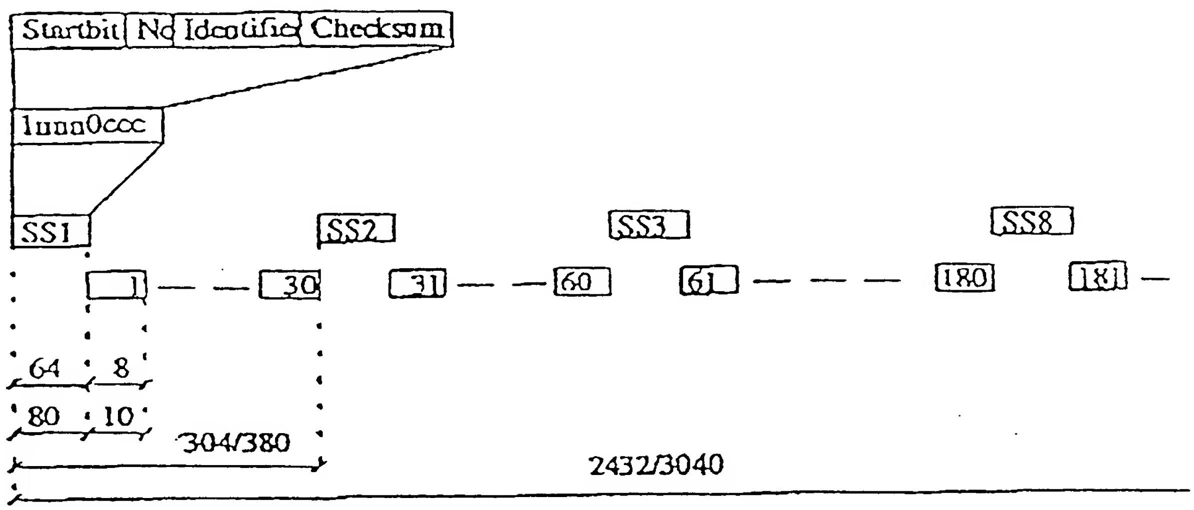

Host Computer System
ORDER
LIGHT FUNC. STATUS
FAILED UNITS
ALARM
CU
ORDER
STATUS
FAIL
SCM
ORDER
STATUS
LMS

Fig. 10


Startbit
No
Identifier
Checksum
1nnn0ccc
SS1
SS2
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31
60
61
180
181
64
8
80
10
304/380
2432/3040

Fig. 11

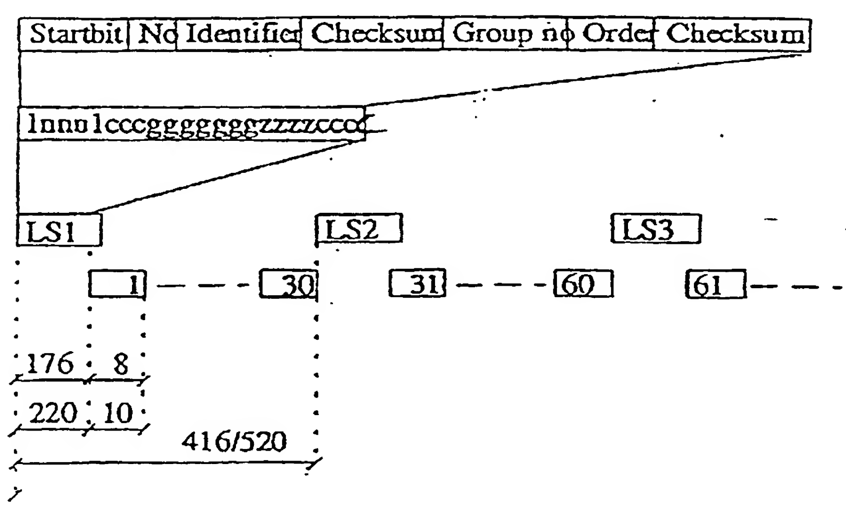
Startbit
No
Identifier
Checksum
Group no
Order
Checksum
1nnn1cccggggggggzzzzccc
LS1
LS2
LS3
1
30
31
60
61
176
8
220
10
416/520

Fig. 12

INTERNATIONAL SEARCH REPORT

International Application No
SE 95/00251

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B37/03 H04B3/54 H02J13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H05B H04B H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 445 773 (TOSHIBA) 11 September 1991 cited in the application see abstract; figures 1-9	1
A	US,A,4 024 528 (BOGGS) 17 May 1977 see column 3, line 26 - column 3, line 66; figures 1,2	1
A	US,A,4 845 466 (HARITON) 4 July 1989 see column 3, line 16 - column 4, line 15; figure 1	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
13 June 1995	28.06.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Speiser, P

INTERNATIONAL SEARCH REPORT

International Application No
PC[illegible]E 95/00251

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0445773	11-09-91	JP-A- 3257793	18-11-91
		JP-A- 3272596	04-12-91
		JP-A- 4147599	21-05-92
		US-A- 5099177	24-03-92
US-A-4024528	17-05-77	NONE	
US-A-4845466	04-07-89	NONE	

Form PCT/ISA/210 (patent family annex) (July 1992)

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